ZOOLOGICAL SCIENCE **24**: 643–647 (2007)

Vertical Movements of a Mekong Giant Catfish (*Pangasianodon gigas)* in Mae Peum Reservoir, Northern Thailand, Monitored by a Multi-Sensor Micro Data Logger

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The vertical movements of one Mekong giant catfish *Pangasianodon gigas* were monitored for 3 days in August 2004 using a depth-temperature micro data logger. The logger was recovered using an innovative time-scheduled release system and located by searching for VHF radio signals. The logger was found approximately 2.2 km away from the release point and provided (n=705,128) depth and temperature data collected over a period of 98 hours following the release. The fish spent more than 99% of its time at less than 3 m below the surface. The maximum swimming depth was 5.6 m. No sharp thermocline was present during the experiment. Temperature did not have any detectable effect on the pattern of vertical movement of the fish. The dissolved oxygen concentration (DO) was stratified, with a concentration of >60% saturation in the first 3 m below the surface falling to 10% saturation at depths lower than 4 m. This specific DO stratification was found to limit the vertical movement of the catfish.

Key words: endangered species, hatchery-reared fish, time-schedule release system, pop-up system

INTRODUCTION

Understanding the movement patterns of a target species is indispensable for successful stock enhancement. Furthermore, the relationship between movement patterns and the physiological and environmental conditions (*e.g.*, temperature and dissolved oxygen) must be considered for effective fishery management. Movement patterns as well as the relationship between movement, vertical distribution of the water temperature, and the condition of dissolved oxygen, have been investigated in many freshwater, marine, and anadromous fishes. The results have contributed to effective fisheries management and the prevention of bycatch (Rahel and Nutzman, 1994; Brill, 1994; Block *et al*., 1997; Brill *et al*., 1999; Musyl *et al*., 2003; Cartamil and Lowe, 2004).

The Mekong giant catfish *Pangasianodon gigas* is endemic to the Mekong River Basin. Historically, this species was distributed throughout the basin from China to Vietnam, but it now appears to be limited to the Mekong River and its tributaries in Thailand, Lao People's Democratic Republic, and Cambodia. This catfish is one of the largest freshwater fishes in the world, measuring up to 3 m in length and weighing in excess of 300 kg (Rainboth, 1996). This species has one of the fastest growth rates of any fish in the world and can reach 150–200 kg in 6 years (Rainboth, 1996). In Southeast Asia, this catfish has historically been popular with the local people, and folklore and hallowed traditions are associated with it. The catfish is also one of the most important fisheries species of the Mekong River Basin and is sold for high prices in Southeast Asia. The catch number of wild catfish in the Mekong River has declined due to development of the river and overfishing (Hogan, 2004). In Thailand, only the fishery cooperative of the Chaing Kong District in Chaing Rai Province is allowed to capture wild catfish in the Mekong River, while there is no fishery regulation in other countries. From 1986–2003, the maximum annual catch of 69 fish in the district mentioned above was reported in 1990, whereas no catfish were caught from 2001–2003. This decline in catch number implies that the wild catfish may be close to extinction. Hogan *et al*. (2004) estimated that the total number of wild catfish in the Mekong River has decreased by approximately 90% during the past two decades. At present, the catfish is listed in

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doi:10.2108/zsj.24.643

CITES Appendix I and on the IUCN Red List of threatened species as a critically endangered species. It is important for local culture and the conservation of this species to coexist.

Artificial breeding programs for the Mekong giant catfish were developed in 1983 and have facilitated the production of catfish fry in Thailand. Hatchery-reared juvenile and young immature catfish were released into lakes and reservoirs as well as the Mekong River by the government of Thailand in order to enhance the stock (Meynell, 2003). The behavior of these catfish after their release into natural conditions remains largely unknown (Bao *et al*., 2001, Meynell 2003). Especially in enclosed areas, the vertical distribution of dissolved oxygen in the water is an important factor affecting fish behavior, since exposure to hypoxic conditions for a long time may lead to death (Davis, 1975; Kramer, 1987; Rahel and Nutzman, 1994; Ultsch *et al*., 1999). When fish reared in a hatchery for a long time are released into the wild, they experience hypoxia, but may not display appropriate avoidance behavior. Some fishes respond physiologically to hypoxia within a few seconds (Davis, 1975). We measured the vertical movements of a hatchery-reared fish on the second scale, in order to gain better insight into the relationship between the movements of the fish and dissolved oxygen concentration. In this paper, we report the vertical movements of a hatchery-reared fish in relation to hypoxic conditions.

MATERIALS AND METHODS

Fish and tagging

One hatchery-reared immature Mekong giant catfish was used for this experiment. The fish (total length, 79 cm; body weight, 4.5 kg) was estimated to be 6–11 years old, and to be immature. The fish was released at the shoreline on the dammed side of the Mae Peum Reservoir (Fig. 1) on 2 August 2004, after instruments had been attached to the back as follows.

Depth-temperature data loggers capable of monitoring free-ranging fish behavior at regular 1-s intervals are available. However, these loggers require the recapture of the animals to retrieve the data, which is very difficult with free-ranging Mekong giant catfish. As a solution, we used a newly developed time-scheduled release system. The system releases the data logger from the fish and allows the logger to be retrieved using VHF radio signals so that recapture of the animals becomes redundant.

A multi-sensor micro data logger (UME 190DT; 15 mm in diameter, 49 mm in length, 14 g in air; Little Leonardo, Tokyo, Japan) with 12-bit resolution (accuracy ±5 cm), which recorded swimming depth and temperature at 1-s intervals, was attached to a float made of balsa wood, in which a VHF radio transmitter with a 20-cm antenna (MBFT-7M; 60 BPM, battery life 14 days, 1.8 g in air Lotek; Ontario, Canada) was embedded (Fig. 2). A plastic cable connected to a time-scheduled mechanism (Little Leonardo, Tokyo, Japan) was attached through the back muscle near the dorsal fin of the catfish while under anesthesia induced with 1 ml/L 2-phenoxyethanol. The logger release mechanism included a timer, which triggered activation approximately 98 hours after the fish was set free. Once the detachment mechanism had been activated, the plastic cable was severed by electric charge from the battery of the device, and the float was detached from the catfish. The float rose to the surface and was located using VHF radio signals. A preliminary experiment demonstrated that there appeared to be no discernible effects on the swimming behavior of the fish, before or after the release mechanism had been triggered. Furthermore, no infection of the fish skin due to the float and the plastic cable fixation was observed after the logger release mechanism had been activated. The resulting hole in the skin healed without complications.

Mae Peum Reservoir was constructed by damming a river. The area of the reservoir is approximately 8.3 km^2, and the maximum depth approximately 15 m. The bottom topography was surveyed by using an echo sounder (Fig. 1). The water level of the reservoir is regulated by the overflow and was mostly stable during the year of the study.

Water temperature and dissolved oxygen

The vertical profiles of water temperature and dissolved oxygen were measured at 1-m depth intervals at seven sites (Fig. 1) during the day on 2 August 2004 using a dissolved-oxygen meter (Model 58, YSI Inc.).

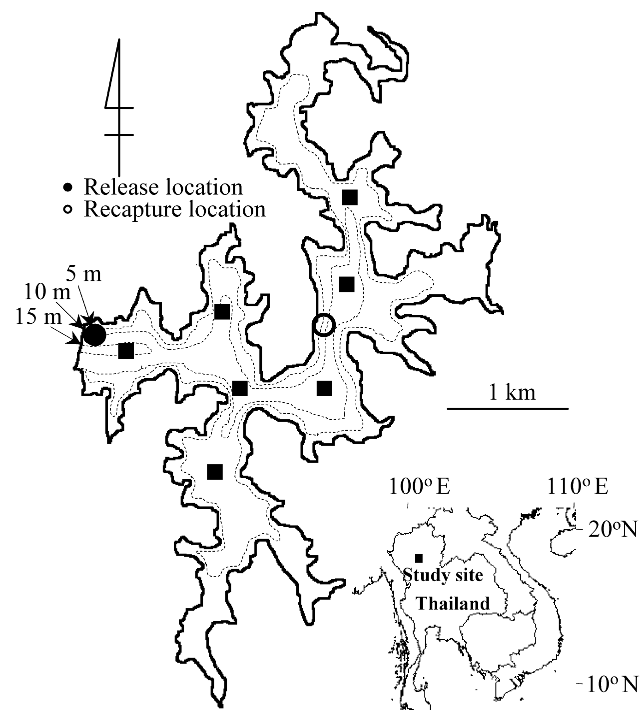

Fig. 1. Map of the Mae Peum Reservoir in Phayao Province, northern Thailand. Filled and open circles represent the locations of fish release and data-logger recapture, respectively. Filled squares represent the positions where water temperature and dissolved oxygen were measured.

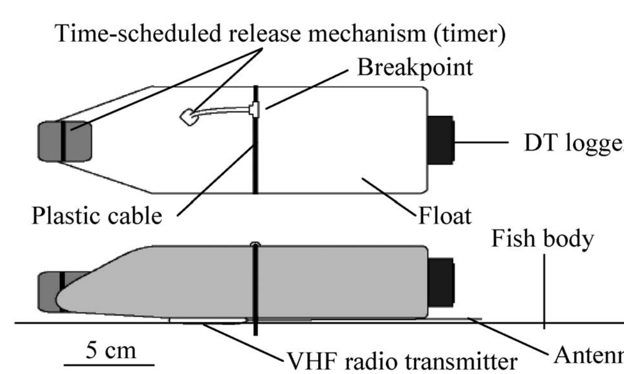

Fig. 2. Top (top) and side (bottom) views of the micro data-logger system used on the Mekong giant catfish in Mae Peum Reservoir, northern Thailand, August 2004. The total weight of the system was approximately 45 g in air.

RESULTS

The time-scheduled release mechanism worked as expected, and the float was successfully retrieved from the fish. It was found approximately 2.2 km away from the fish release point, 5 min after activation of the release mechanism (Fig. 1). The depth-temperature logger provided approximately 98 hours of data. The differences in ambient water temperature during the first 36 hours were greater than those in the following hours. Since the fish may have been distracted by the float system in the beginning of the experimental period, these data were excluded from analysis, so that the final data set considered amounted to 62 hours (swimming depth n=224,556, water temperature n=224,556).

The fish spent more than 99% of its time in the first 3 m of water column. Average swimming depth±S.D. was 1.4±0.7 m (n=224,556). The fish was spotted several times swimming normally at the surface of the reservoir. The water temperature (average±S.D., 29.0±0.3°C; n=224,556) recorded by the logger was almost constant over the swimming depth of the fish. The fish remained in the epilimnion during the whole experiment. The average hourly swimming depths±S.D. for day (06:00–19:00) and night (19:00–06:00) were 1.42±0.36 m (n=35) and 1.38±0.52 m (n=28), respectively. The fish spent its time at slightly greater depth during the day than at night. The averages of the standard deviations calculated from the mean hourly swimming depths during the middle of the day (10:00–14:00) and the middle of the night (22:00–02:00) were 0.51 m (n=12) and 0.33 m (n=10), respectively. The vertical distribution of the fish's movement was significantly greater during the day than at night (Mann-Whiteny *U*-test, *U*=29, P<0.05). The daily average water temperatures±S.D.s ranged from 28.6±0.2°C (n=30,157) to 29.0±0.3°C (n=46,800) in the day (06:00–19:00) and from 28.9±0.2°C (n=39,600) to 29.3±0.3°C (n=39,600) at night (19:00–06:00). The fish almost constantly showed vertical movement during the day, but swimming depth did not change during the night (Fig. 3). The maximum swimming depth was 5.6 m.

Vertical distribution of water temperature and dissolved oxygen at the monitoring stations

Water temperature was almost uniform from the surface layer to a depth of 4 m (Fig. 4). There was no sharp thermocline. From a depth of 4 m, water temperature gradually decreased towards the reservoir bottom (Fig. 4). Average water temperature ranged from 29.5°C (surface) to 24.8°C (bottom). Dissolved oxygen stratification was found up to a depth of 4 m. Average dissolved oxygen ranged from 89.9%, 6.8 mg/l (surface) to 2.2%, 0.19 mg/l (bottom). Dissolved oxygen levels below 4 m were uniformly less than 10% saturated.

DISCUSSION

Vertical movement determined using a data logger

The Mekong giant catfish in Mae Peum Reservoir repeatedly moved vertically between the surface and middle depth (3 m) during the day, whereas it did not change its swimming depth at night (Fig. 3). The fish tended to spend time at slightly greater depths during the day than during the

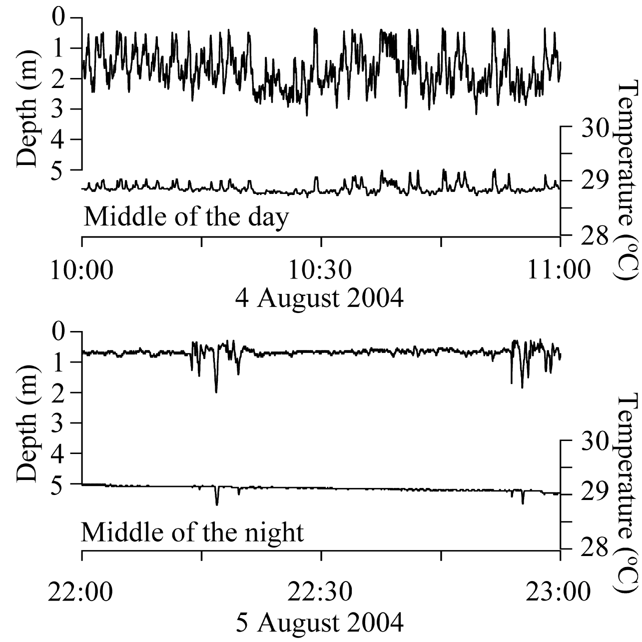

Fig. 3. Typical vertical movement of a Mekong giant catfish during the day and at night with vertical profiles of water temperature; Mae Peum Reservoir, northern Thailand, in August 2004.

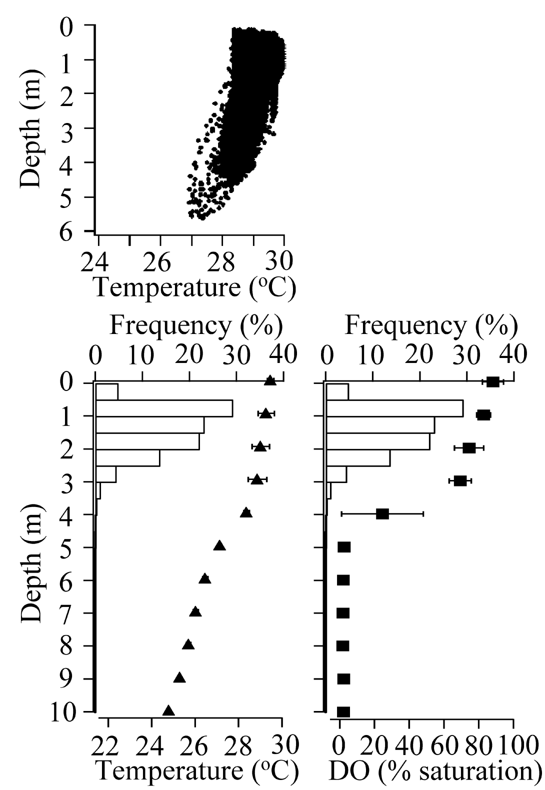

Fig. 4. Swimming depth and water temperature recorded by the fish (upper panel). Frequency of swimming depths with the vertical distribution of water temperature and dissolved oxygen at seven sites (lower panels). Triangles indicate temperatures; squares indicate dissolved oxygen (DO) concentrations; horizontal bars indicate S.D (n=2–7).

night, and the vertical distribution of the fish's swimming location was slightly greater during the day than at night. Although some fishes exhibit changes in swimming depth, vertical distribution, and activity between day and night (Musyl *et al*., 2003; Cartamil and Lowe, 2004; Mitamura *et al*., 2005), there were no significant differences in this study. The fish in this study spent over 99% of its time at less than 3 m below the surface, and its narrow range of vertical movement could not be assigned to different ecological uses in swimming depth.

Vertical movement in relation to environmental conditions

The observed fish spent over 99% of its time above a depth of 3 m, although the bottom of the reservoir did not limit vertical movement (Fig. 1). The vertical movements of some fishes may be generally limited by the range or rate of change in water temperature, rather than by its absolute temperature (Brill, 1994; Brill *et al*., 1999; Cartamil and Lowe, 2004). In this study, there was no sharp thermocline, and water temperature differences between the surface and the bottom were less than 5°C (Fig. 4). Although during the day the surface water was heated, the relatively warm water directly flowed out and only a weak thermocline occurred in the reservoir. The stable water temperature of the reservoir might be caused by the overflow regulation of the water level, and is assumed to have little effect on fish behavior. Therefore, during the period of overflow regulation, fish may not be limited in their movement by the vertical distribution of water temperature.

In contrast to the temperature conditions, dissolved oxygen was stratified at a depth of 4 m. Dissolved oxygen concentrations below 4 m were uniformly less than 10% (temperature 24.8–27.2°C). Reductions in the level of available oxygen have profound effects on many physiological, biochemical, and behavioral processes in fish (Davis, 1975; Brill, 1994). The thresholds for the lower limit of dissolved oxygen influencing fish behavior, metabolic rate, swimming ability, and viability differ among fish species (Davis, 1975; Wannamaker and Rice, 2000). However, most fishes cannot survive for long periods below a saturation of 10% (Davis, 1975). We therefore conclude from this study that the vertical movement of the fish was limited by the stratification of dissolved oxygen. This is strongly supported by evidence that fish generally attempt to move away from water with low levels of oxygen (Davis, 1975; Weltzien *et al*., 1999; Suthers and Gee, 1986; Pihl *et al*., 1991; Wannamaker and Rice, 2000).

In this study, we found that the vertical movements of one Mekong giant catfish in the Mae Peum Reservoir were limited by dissolved oxygen stratification. This indicates that hatchery-reared catfish may recognize and avoid hypoxic conditions. A hatchery-reared fish released into the wild may not die due to hypoxic conditions. Many researchers have reported that the vertical movements of many freshwater and marine fishes are limited by dissolved oxygen stratification and thermoclines, although some fishes (*e.g*., tuna, mudminnow) make repeated efforts to dive below these limits (Pihl *et al*., 1992; Brill, 1994; Rahel and Nutzman, 1994; Takai *et al*., 1997; Ultsch *et al*., 1999; Dagorn *et al*., 2000; Baldwin and Beauchamp, 2002; Musyl *et al*., 2003; Cartamil and Lowe, 2004; Wilson *et al*., 2005). Various explanations have been suggested for these vertical movements with respect to physical environmental conditions, most of which focus on prey acquisition as the primary motivation for diving activity (Rahel and Nutzman, 1994; Musyl *et al*., 2003). In general, exposure to hypoxia for a long time may have a large effect on fish behavior and respiration activity and may eventually lead to death (Davis, 1975; Kramer, 1987). In this study, the monitored catfish rarely moved below the dissolved oxygen stratification layer. The Mekong giant catfish is considered to be herbivorous. Thus, the fish did not have to make repeated efforts to dive below the dissolved oxygen stratification layer to feed because algae were abundant above the stratified layer at the study site near the shore of the reservoir. In this study, we report the vertical movements of a single catfish in relation to hypoxic conditions. Further comprehensive studies on movements and behavior are necessary for successful fisheries management and conservation of the species.

ACKNOWLEDGMENTS

We sincerely thank all staff of Phayao Inland Fisheries Research and Development Center, Thailand, for their kind support, advice, and contributions to the research in Thailand. We would like to express appreciation to our colleagues T. Nakao, J. Okuyama, T. Yasuda, K. Ichikawa, H. Tanaka and Y. Shimizu for their kind assistance and discussions. This study was partly supported by Grants-in-Aid for Scientific Research (13375005, 12556032, 14560149 and 15-5686) and the Information Research Center for Development of Knowledge Society Infrastructure, the Ministry of Education, Culture, Sports, Science and Technology.

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(Received September 23, 2006 / Accepted February 20, 2007)